Nanohole Arrays: Enhancing Transmission Surface Plasmon Resonance (T-SPR) Signal

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ABSTRACT

A variety of man-made environments commonly harbor Legionella species. Legionnaires' disease originates from the Legionella bacteria contributing to 15 to 20% mortality rate. One species of Legionella, L. pneumophila, seems to be responsible for 90% of all reported cases. We propose to develop a nanoplasmonic transmission surface plasmon resonance (SPR) biosensor to detect legionella bacteria. The gold substrate of the biosensor will be milled with a Focused Ion Beam on a Carl Zeiss Auriga-BU FIB FESEM Microscope using the Nano Patterning and Visualization Engine (NPVE). The gold surface will have ten by ten arrays of nanohole configurations arranged in an a cell. The cells will be arranged in a ten by ten grid to form the surface of the nanoplasmonic biosensor. Following the milling, we will functionalize the gold surface with capture probes specific for 16S rRNA.

BACKGROUND

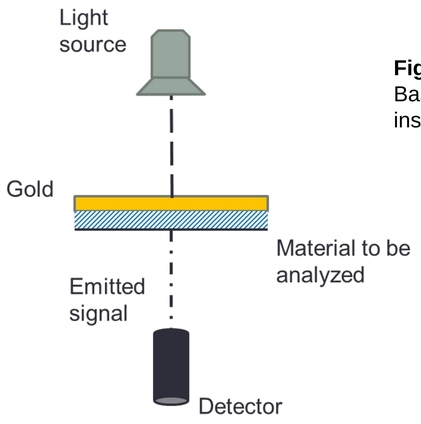

Figure 1: (left) Basic TSPRi instrumentation

A beam of light aimed at a gold foil with a frequency matching the natural frequency of the surface plasmon will cause the surface plasmon to resonate, magnify and emit the wavelength of its resonance. By aiming a beam of light at the surface of a thin metal bordering another material, the surface plasmon of the thin metal will be affected by the properties of the other material and resonate differently. So, this will be seen as a wavelength shift in the emitted signal indicating the presence, and quantity, of the sample material.

T-SPR Signal Enhancement

Nanostuctures, structures smaller than the wavelength of light, interact with the light through an effect called Local Surface Plasmon Resonance (LSPR). Local Surface Plasmon Resonance magnifies the signal emitted from the gold foil which matches the tuned frequency of the nanostucture. Our research is based on the previous work by Dr. Malic and co-workers (*Lab on a Chip*), and the nanostructure they used, called a nanograting, shown to the right. The nanostructure we are developing is a cell of nanohole arrays which could be more effective than the nanograting.

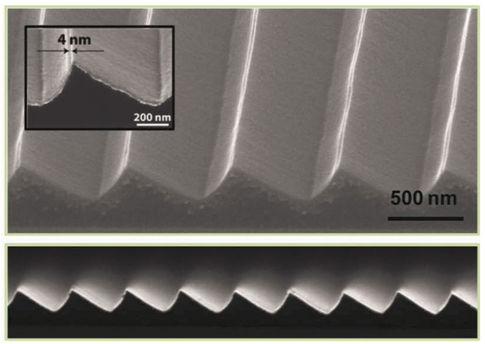

Figure 2: (Top) Nanograting
Lidija Malic, Keith Morton, Liviu Climea and Teodor Veres ***Lab on a Chip****, 2013, 13, 798-810*

METHODS

NANOHOLE ARRAY

The nanohole array is composed of a series of circles made of a number of holes which vary in size, designed by Dr. Malic. This design acts as a lens to focus the light to the middle of the circle by increasing the intensity of the emitted light. Under these conditions, the sensor chip surface is ultrasensitive to any type of perturbation. The nanohole array is milled on a gold substrate using a Focused Ion Beam (FIB) and the NPVE computer program. The NPVE program can be programmed to mill up to ten nanohole arrays at one time. The gold sample is cleaned then prepared in the SEM/FIB instrument. Once the FIB is focused and coincides with the SEM beam, the NPVE program array is set up and then milling begins.

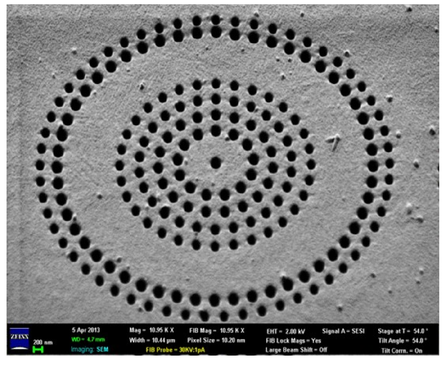

Figure 3: Nanohole array milled by Stephen Vance and Dr. Yang

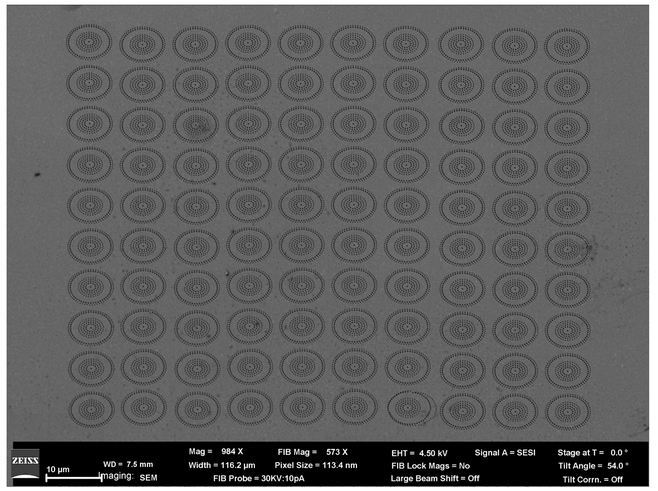

Figure 4: Cell of Nanohole arrays

FURTHER STUDIES

To use the nanohole arrays, they must be arranged in cells of ten by ten nanohole configurations. These cells must then be put into arrays for use by Transmission SPR imaging. A 3 x 3 array of cells of the nanohole arrays has been milled to date but is too small to test so a 5 x 5 array of cells must be created in order to test the signal enhancement of the nanohole arrays. If this shows promise, then a larger 10 x 10 array will be milled. This may then be used in conjunction with surface binding of other substances to determine if the design will adequately enhance the signal of the light for use in T-SPR imaging and eventually in a biosensor for legionella bacteria.

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